COSEWIC
Assessment and Status Report

on the

Hairy Braya
Braya pilosa

in Canada

ENDANGERED
2013

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC would like to acknowledge James G. Harris for writing the status report on Hairy Braya, *Braya pilosa*, prepared under contract with Environment Canada. This report was overseen and edited by Bruce Bennett, Co-chair of the COSEWIC Vascular Plants Specialist Subcommittee.

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Hairy Braya — photo by J. Harris.

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COSEWIC
Assessment Summary

Assessment Summary – May 2013

Common name
Hairy Braya

Scientific name
Braya pilosa

Status
Endangered

Reason for designation
This plant is restricted globally to a very small area in the Northwest Territories. It is endangered by the loss of habitat through very rapid coastal erosion and saline wash resulting from storm surges, and by permafrost melting. These events appear to be increasing in frequency and severity as a consequence of a significant reduction in sea ice cover on the Beaufort Sea and changes in weather patterns. These indirect impacts of climate change are expected to continue into the foreseeable future.

Occurrence
Northwest Territories

Status history
Designated Endangered in May 2013.

COSEWIC
Executive Summary

Hairy Braya
Braya pilosa

Wildlife Species Description and Significance

Hairy Braya (*Braya pilosa*) is a long-lived perennial mustard with one to many stems 4.0-12 cm long, erect to ascending to almost prostrate and moderately to densely hairy. It is distinguished from other *Braya* species by its large flowers and globose (nearly spherical) fruits with very long persistent styles.

Hairy Braya is a narrow endemic of arctic Canada that likely played a crucial role in the evolution of other *Braya* species.

Distribution

Hairy Braya is only known to occur on Cape Bathurst in the Northwest Territories of Canada. There are 13 populations on the northern portion of Cape Bathurst and on the nearby Baillie Islands.

Hairy Braya is restricted to an area that remained ice-free during the Pleistocene and it has apparently been unable to move into surrounding glaciated areas over the millennia since the ice receded.

Habitat

Hairy Braya grows on bluffs and dry uplands on patches of bare, calcium-rich sandy or silty soils. It typically grows with Arctic Willow, Entire-leaved Mountain-avens, and various grass species including Richardson's Fescue, Arctic Wheatgrass, Arctic Bluegrass, and Alkali Grass.These habitats appear to be quite limited on Cape Bathurst. Patches of suitable habitat are often separated by large areas of wet tundra, or by eroded cliffs or salinized soils. Coastal areas southwest of Cape Bathurst are rapidly eroding, and a decrease in arctic sea ice is likely hastening the erosion of Hairy Braya habitat along the coast.

Biology

Hairy Braya was lost to science from 1850 to 2004. As a result, very little is known about the biology of the species. However, the large, fragrant flowers suggest that the plant is insect-pollinated, and seeds germinate readily.

There is some genetic and morphological evidence that two related species, Smooth Braya and Greenland Braya may have arisen from Hairy Braya, and it is possible that hybridization between these species, both of which overlap in distribution with Hairy Braya, may be ongoing.

Population Sizes and Trends

Precise counts of the number of individuals have not been made, but estimates of the number of mature individuals observed in 2011 range from about 12,000 to 16,000. Populations on coastal bluffs subject to rapid erosion are clearly at risk of declining. The total number of individuals in one coastal population plummeted between 2004 and 2011. It can be expected that similar populations on eroding shorelines will be similarly affected. Trends and fluctuations in population sizes on protected sections of the coast and on inland bluffs have not been determined, but population sizes appear to be stable.

Threats and Limiting Factors

The most obvious threat to Hairy Braya is a loss of habitat due to rapid erosion and saline wash of coastline habitat resulting from storm surges and permafrost melting. These events appear to be increasing in frequency and severity as a consequence of a substantial reduction in ice cover on the Beaufort Sea over the past few decades. These impacts of anthropogenic climate change are expected to continue into the foreseeable future, and therefore it is unlikely that coastal erosion rates will decrease.

Protection, Status, and Ranks

Hairy Braya is ranked as critically imperilled globally (G1) and nationally (N1) by NatureServe, and has been assessed as Threatened in the Northwest Territories.

Due to the remoteness of Cape Bathurst, Hairy Braya faces little direct threat from human activities. Cape Bathurst includes the calving grounds of the Cape Bathurst caribou herd and a local conservation plan recommends that the area be managed so as to eliminate, to the greatest extent possible, potential damage and disruption.

TECHNICAL SUMMARY

Braya pilosa
Hairy Braya — Braya poilu
Range of occurrence in Canada (province/territory/ocean): Northwest Territories

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2008) is being used). *Generation time is at least 10 years, and likely 20+years. The age of the youngest and oldest breeding individual has not yet been determined.*	10+ years based on other *Braya* species.
Is there a [observed, inferred, or projected] continuing decline in number of mature individuals? *Coastal populations are declining due to erosion, but inland populations are stable.*	Yes
Estimated percent of continuing decline in total number of mature individuals within 2 generations.	2-5%
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. *Several hundred mature plants were lost between 2004 and 2011 due to erosion; however only a single population was known until 2011 so the total loss cannot be quantified.*	unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. *The total population is projected to decline by 5% over the next 10 years, based on the loss of coastal populations.*	5% decrease
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future. *Populations in coastal areas subject to erosion will continue to be eliminated, but once they are gone, remaining populations are likely to remain stable.*	unknown
Are the causes of the decline clearly reversible and understood and ceased? *Decline resulting from increase erosion from reduced sea ice is understood but not reversible within a useful timeframe.*	No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	250 km²
Index of area of occupancy (IAO). *This is a minimum estimate that is likely to increase with more survey effort.*	64 km²+
Is the total population severely fragmented?	No
Number of locations* *Locations are based on the impact of the most plausible threats, such as coastal erosion, potential effects of storm surges, and potential flooding.*	5

*See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Is there an [observed, inferred, or projected] continuing decline in extent of occurrence? *If the most westerly populations are lost there will be a decline in extent of occurrence.*	Yes, observed
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? *The loss of four at-risk coastal populations would reduce the IAO by 16 km².*	Yes, observed and projected
Is there an [observed, inferred, or projected] continuing decline in number of populations? *Four or perhaps five coastal populations will likely be lost to erosion.*	Yes, observed and projected
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Yes projected.
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? *Coastal habitat is rapidly eroding.*	Yes, observed
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population (major threat)	N Mature Individuals
1 (storm surge)	32
2 (storm surge)	240
3 (coastal erosion)	160
4 (coastal erosion)	160
5 (coastal erosion)	(>240 but <800)
6 (storm surge)	>8,000
7 (storm surge)	80
8 (storm surge)	80
9	40
10	(>240 but <800)
11 (coastal erosion)	(>240 but <800)
12 (coastal erosion)	(>240 but <800)
13	(>240 but <800)
Total	12,000-16,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not Done

Threats (actual or imminent, to populations or habitats)

Loss of habitat due to rapid erosion and saline wash of coastline habitat resulting from storm surges and permafrost melting. These events appear to be increasing in frequency and severity as a consequence of a significant reduction in ice cover on the Beaufort Sea over the past few decades. These indirect impacts of anthropogenic climate change are expected to continue into the foreseeable future, and therefore it is unlikely that coastal erosion rates will decrease.

*See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? *The species is found only in Canada.*	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	The species is found only in Canada.
Is there sufficient habitat for immigrants in Canada?	N/A
Is rescue from outside populations likely	No

Status History

COSEWIC: Designated Endangered in May 2013.

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Endangered	B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v)
Reasons for designation: This plant is restricted globally to a very small area in the Northwest Territories. It is endangered by the loss of habitat through very rapid coastal erosion and saline wash resulting from storm surges, and by permafrost melting. These events appear to be increasing in frequency and severity as a consequence of a significant reduction in sea ice cover on the Beaufort Sea and changes in weather patterns. These indirect impacts of climate change are expected to continue into the foreseeable future.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not met. There are no data on the extent of decline. Declines cannot be inferred with certainty, although there is the possibility of future declines due to storm surges.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v). EO and IAO are well below thresholds for Endangered, and the species occurs at 5 locations. There is an observed loss of EO, and IAO, and projected decline in area, extent of habitat, number of locations, and number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals): Not met. The number of mature individuals exceeds thresholds.
Criterion D (Very Small or Restricted Total Population): Comes close to meeting Threatened D2, with a small IAO and the threat of storm surge at some populations, but some populations are not under imminent threat.
Criterion E (Quantitative Analysis): Not done.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2013)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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Appendix A: Extent of the ice at the last glacial maximum, from Dyke *et al.* (2003). Shortly after glaciers retreated Cape Bathurst and Baillie Islands were part of a large glacio-fluvial delta. 30

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name:	*Braya pilosa* Hooker
Synonyms:	*Braya purpurascens* (R. Brown) Bunge ex Ledebour subsp. *pilosa* (Hooker) Hultén
Common name:	Hairy Braya; Hairy Northern Rockcress; Hairy Rockcress; Pilose Braya; Braya poilu
Family:	Brassicaceae (Cruciferae), Mustard Family
Major plant group:	Eudicot flowering plant

Morphological Description

Hairy Braya is a long-lived perennial with one to many stems from a branched root crown (Figure 1). The stems are 4-12 cm long, erect to ascending to almost prostrate, leafless or with a single leaf subtending the lowermost flower or fruit, and densely hairy with straight and tangled hairs. The leaves are basal, 0.7-2 cm in length by 0.7-2.5 mm in width, and moderately to densely hairy. The flowers are borne in dense clusters of five to many and have white petals 4.7-6.6 mm long by 3-5 mm wide (Figure 2). The fruits are ovoid or globose (nearly spherical), 5-6 mm long by 3-4 mm wide, and pubescent with short simple and 2-forked hairs. The style of the mature fruit is 1-2 mm long with a generally broadly expanded stigma (Harris 1985, 2010).

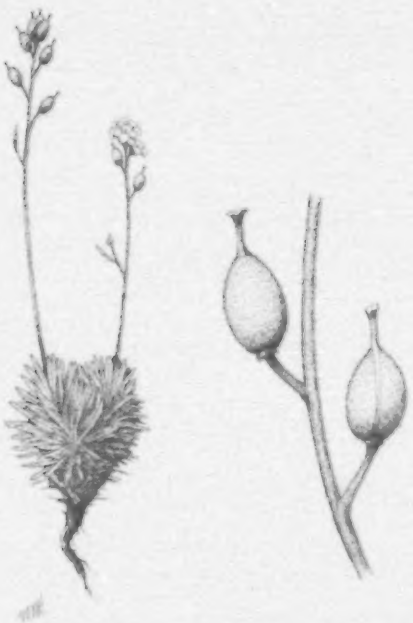

Figure 1. Illustration of Hairy Braya (by Melinda Woolf Harris).

Figure 2. Hairy Braya from the type locality (photo by J. Harris).

The stems, leaves, and fruits of Hairy Braya are usually yellow-green, allowing the plants to be quickly and easily distinguished from the darker green and often purplish-tinged stems, leaves, and fruits of Smooth Braya (*Braya glabella*), which often co-occurs with Hairy Braya.

Population Spatial Structure and Variability

No genetic, demographic or ecological data are available to support recognition of distinct groups within Hairy Braya. Hairy Braya has a suite of attributes that are correlated with out-crossing. These include large petals, exerted styles, scented flowers (Ornduff 1969). However, pollinators have not been observed visiting Hairy Braya flowers, so the extent of potential gene flow between populations has not been determined.

Designatable Units

A single designatable unit is recognized for Hairy Braya in Canada. The entire species is restricted to the north end of Cape Bathurst and nearby Baillie Islands in the Northwest Territories, within a single national ecological area, the Arctic Ecological Area (COSEWIC 2012).

Special Significance

Hairy Braya is a species endemic to the Canadian Arctic, but otherwise lacks any cultural or socio-economic importance. Its scientific value is significant. Hairy Braya survived the Pleistocene glaciations on Cape Bathurst and Baillie Islands (Appendix A) and may be one of the parents of allopolyploid *Braya* taxa that were then able to recolonize glaciated lands at the close of the Pleistocene (Harris 2004).

DISTRIBUTION

Global and Canadian Range

Hairy Braya occurs only in the Northwest Territories of Canada (Hooker 1830; Harris 1985, 2004, 2010, 2012) where it is known from 13 populations of a single metapopulation on the northwestern portion of Cape Bathurst and on nearby Baillie Islands (Figure 3), an area that escaped Pleistocene glaciation (Appendix A; Prest 1969; Dyke *et al.* 2003). The number of populations was determined using definitions developed by IUCN (2008) and strategies for delimiting plant element occurrences from NatureServe (2011). Essentially, plant element occurrences (i.e. groups of Hairy Braya plants) separated from other occurrences by at least one km and isolated by unsuitable habitat are considered to be a population.

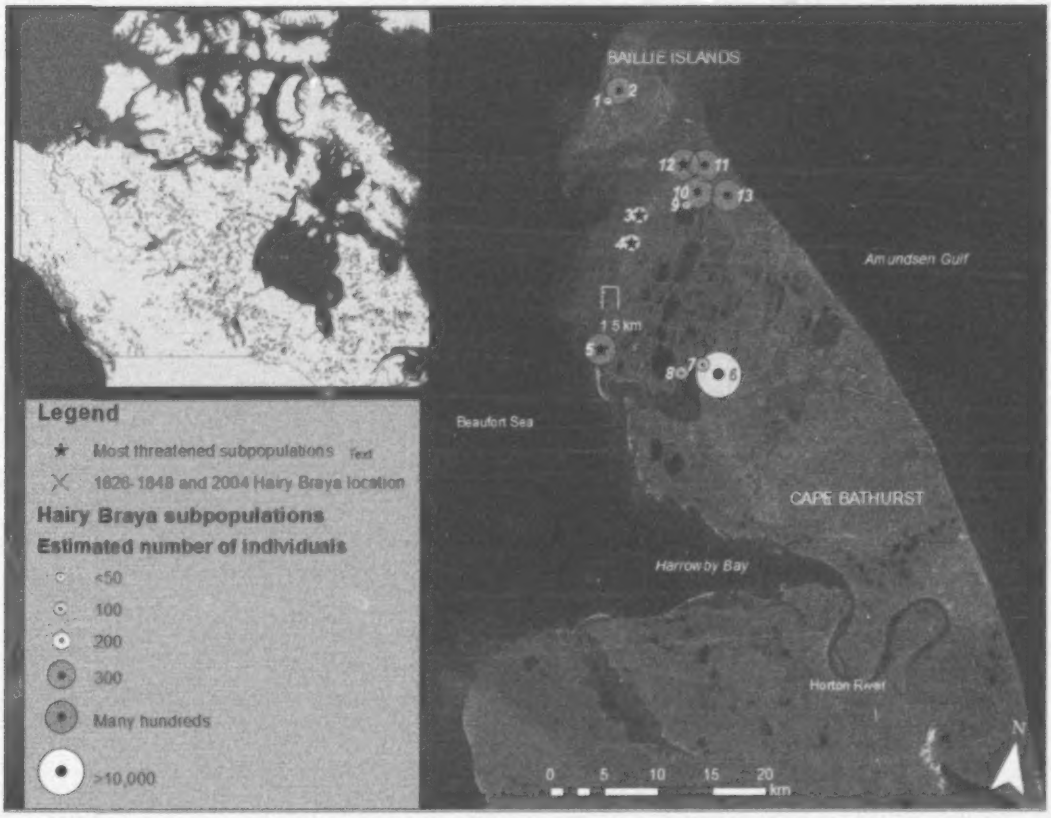

Figure 3. Distribution of Hairy Braya in the NWT (SARC 2012).

Extent of Occurrence and Area of Occupancy

The total extent of occurrence (EO) is approximately 250 km^2 (Figure 4), and the index of area of occupancy (IAO) based on 2 km x 2 km grid squares is 64 km^2 (Figure 5).

Figure 4. Extent of occurrence of Hairy Braya based on element occurrences of the species (yellow dots). Map produced by the Government of the NWT (SARC 2012).

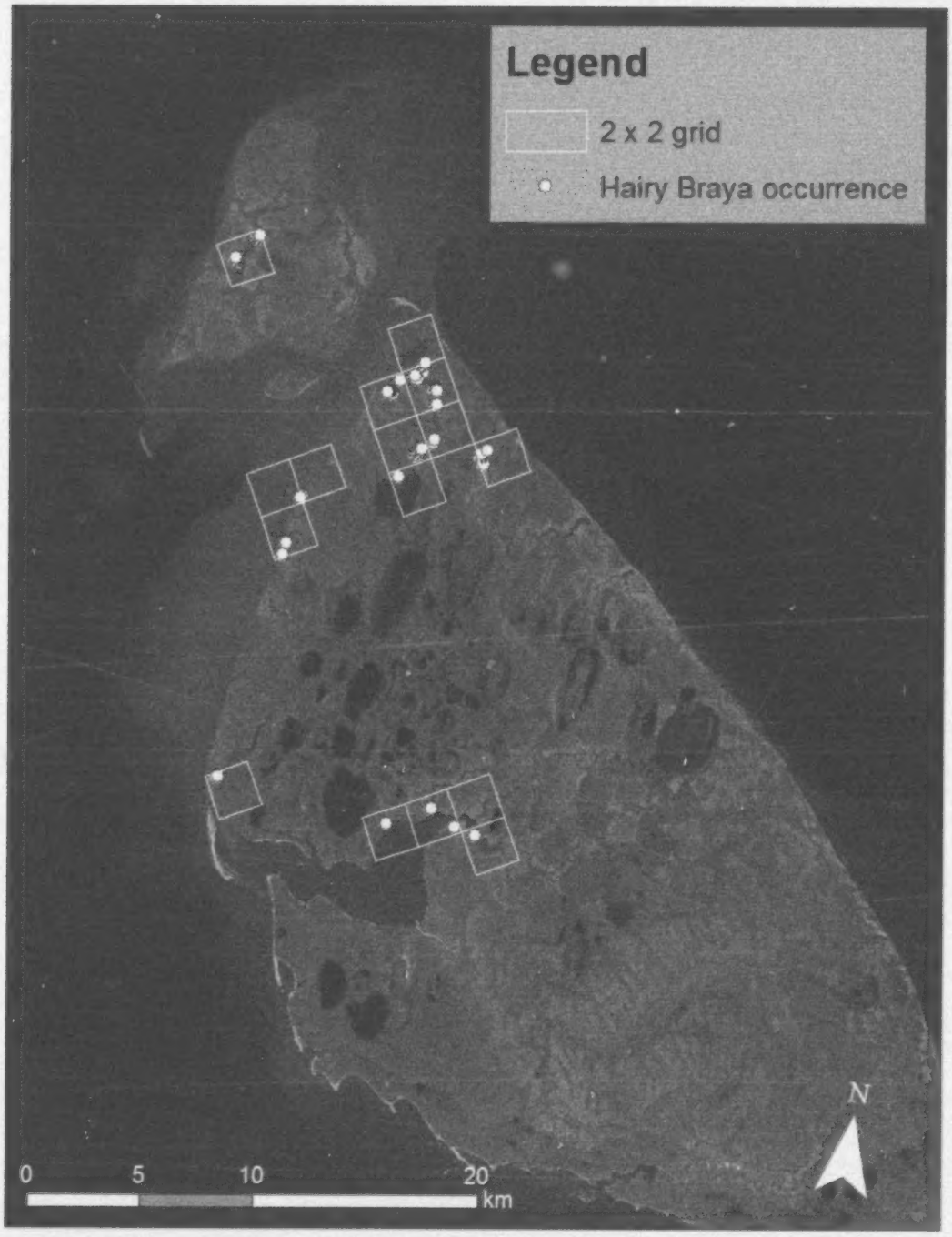

Figure 5. Index of area of occupancy (IAO) of Hairy Braya based on element occurrences of the species (yellow dots). Map produced by the Government of the NWT (SARC 2012).

Search Effort

When he named the species, Hooker (1830) described the type locality of Hairy Braya as "Mouth of Mackenzie River, lat. 70°," based on Richardson's (1828) rather broad conception of the Mackenzie River Delta. This was somewhat misleading to those who have looked for Hairy Braya since 1850. Porsild, for example, made several collections of *Braya* between the mouth of the Mackenzie River and Nicholson Island in Liverpool Bay, where Hooker's site description suggests that Hairy Braya should be found. Although Porsild initially identified his collections as Hairy Braya (Porsild 1943), none of them show the distinctive ovoid fruits, exceptionally long styles, and large flowers of this taxon and fall instead within the normal range of diversity in Smooth Braya.

Harris (2004) provides evidence that all three collections of Hairy Braya up to 1850 came from the same locality, and until 2011 Hairy Braya was known only from this single population on the coast southwest of Cape Bathurst (Harris 2004). However, fieldwork conducted on Cape Bathurst and the Baillie Islands in late July and early August of 2011 led to the discovery of several additional populations of the species and to the discovery that the 2004 population had virtually disappeared from coastal erosion and salt-spray mortality (Harris 2011).

Over a four-day period approximately 60 km in the northern portion of the peninsula were traversed on foot (Figure 6). Information about habitat preferences of the plant was then used for a one-day survey of surrounding areas by helicopter (Figure 6). Although several sites on the eastern coast of the peninsula as far south as the Horton River Delta were surveyed, Hairy Braya was not seen on this side of the peninsula. The available helicopter flight time was not sufficient to determine the southern limits of the plant on the western side of the peninsula (Figure 6).

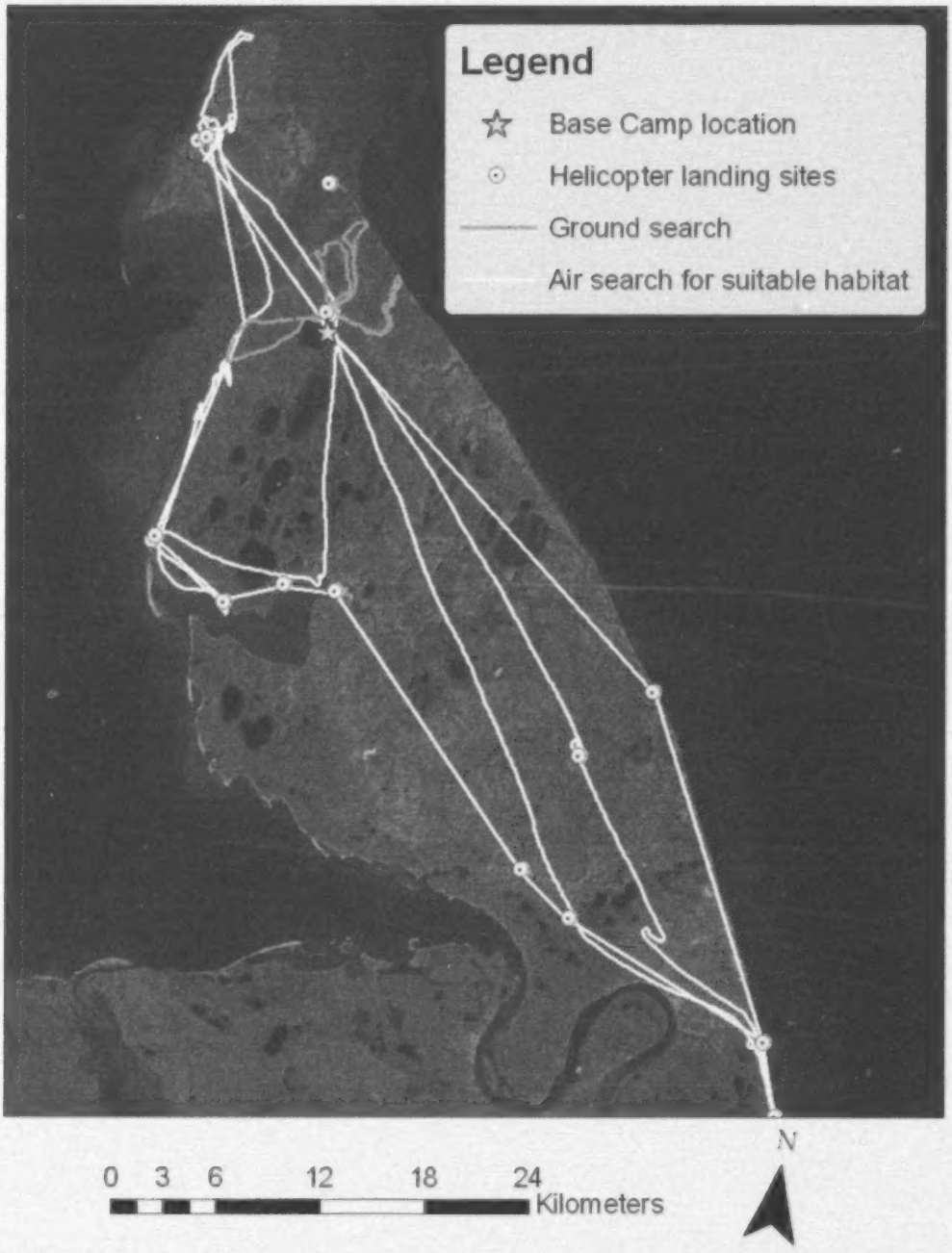

Figure 6. Search effort on Cape Bathurst 2011. Map produced by the Government of the NWT (SARC 2012).

Targeted searches for Hairy Braya since 1850 are limited to a search in 2004 (Harris 2004) and fieldwork conducted near Cape Bathurst in 2011. Hairy Braya has not been found anywhere else but on Cape Bathurst even though a considerable amount of botanical exploration has occurred in surrounding areas (Figures 7 and 8). In addition to Porsild's significant number of collections of *Braya* between the mouth of the Mackenzie River and Cape Parry and on Banks Island, extensive botanical work has been conducted to the west of the Mackenzie River in coastal Yukon and Alaska (Bennett pers. comm. 2012; GNWT 2012). Collections of other *Braya* species housed in the herbaria of the Canadian Museum of Nature, Agriculture and Agri-Food Canada, the University of Alberta, the University of Alaska, the New York Botanical Garden, and the Royal Botanic Gardens at Kew, UK, come from numerous localities spread along the coast both east and west of Cape Bathurst (Figure 8). None of these collections include Hairy Braya from anywhere except Cape Bathurst.

Figure 7. Hairy Braya on Cape Bathurst (green) and collections of other Braya species in Alaska, Yukon, NWT, and Nunavut (red) (adapted from Harris 1985).

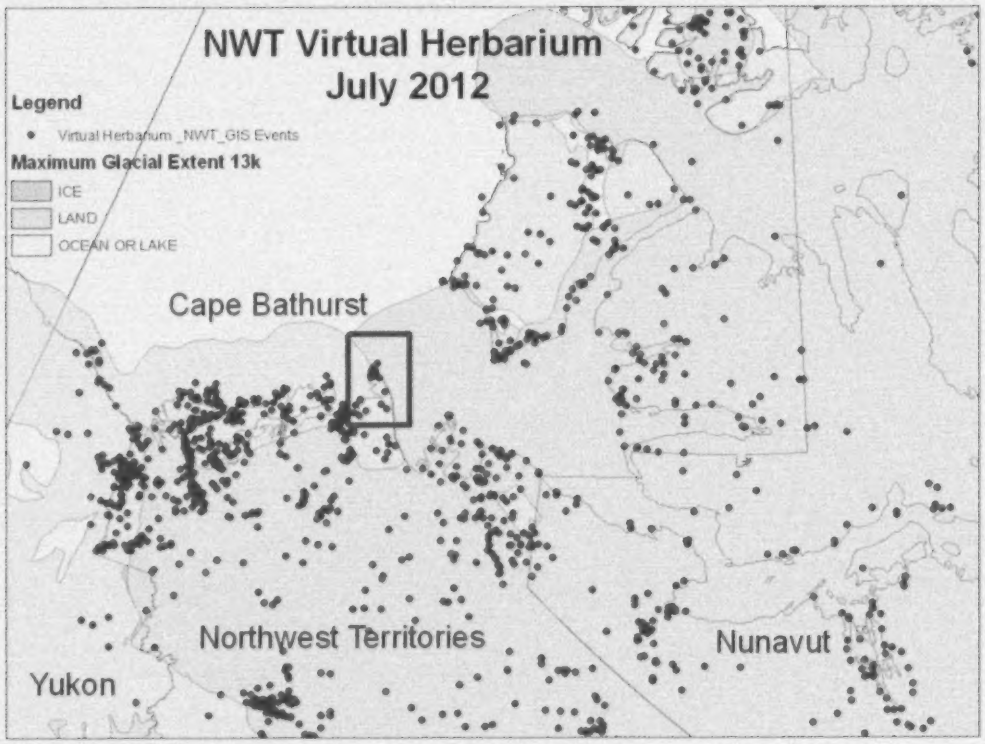

Figure 8. Cape Bathurst (rectangle), collections of vascular plants in Yukon, NWT, and Nunavut and extent of glacier during Wisconsin maximum in northwestern North America. Plant data from NWT Virtual Herbarium (accessed July 2012) and ice extent based on Dyke, A.S., Moore, A., and Robertson, L. 2003. Deglaciation of North America, Geological Survey of Canada Open File 1574, adapted from Harris 1985). NWT Virtual Herbarium (July 2012) contains label information from specimens in DAO, CAN, UA, and uncurated herbaria in Inuvik, NWT.

HABITAT

Habitat Requirements

Hairy Braya is restricted to an area that remained ice-free during the Pleistocene (Prest 1969; Harris 2004) as part of Beringia (Appendix A; NWT PAS Secretariat 2012). The plant occurs on bluffs and dry uplands composed of calcareous sandy loam and silty clay loam soils (Figures 9 and 10).

Figure 9. *Braya pilosa* habitat (photo by J. Harris).

Figure 10. Hairy Braya (*Braya pilosa*) habitat (photo by J. Harris).

The plant communities in which Hairy Braya is found are dominated by Arctic Willow (*Salix arctica*), Entire-leaved Mountain-avens (*Dryas integrifolia*), and various grass species including Richardson's Fescue (*Festuca richardsonii*), Arctic Wheatgrass (*Elymus violaceus*), Arctic Bluegrass (*Poa arctica*), and Alkali Grass (*Puccinellia* spp.) (Harris 2011).

Like other *Braya* species, Hairy Braya appears to be a poor competitor, requiring bare soil to become established (Harris 1985, 2010). Measurements from three Hairy Braya populations showed bare soil cover percentages ranging from 39% to 47% (Harris 2011). The most common cause of bare soils supporting Hairy Braya appears to be seasonal periods of standing water that eliminate most other plant species from small depressions in otherwise dry habitats. Once established, mature Hairy Braya plants tolerate competition with other plant species. In some cases, areas of bare soil occupied by Hairy Braya are the result of the wind erosion of coastal bluffs, and in other cases they are caused by disturbance due to caribou hooves. Freeze-thaw cycles may also create areas of bare soil, as has been observed in Newfoundland (Parsons and Hermanutz 2006).

Habitat Trends

Coastal areas southwest of Cape Bathurst are rapidly eroding, with large mats of turf, some bearing Hairy Braya, sliding down a steep escarpment toward the sea (Figures 11 and 12). Prior to erosion, coastal areas are also subject to storm surges resulting in plant morality due to salt sprays. The well documented decrease in arctic sea ice over the past few decades (e.g. Lindsay and Zhang 2005; Stroeveet *et al.* 2007) has increased the duration and severity of storm surges (Jorgenson and Brown 2005) that are hastening the erosion and salinization of Hairy Braya habitat along the coast, and populations of Hairy Braya in these areas (3, 4, 5 and 12; see starred populations on Figure 3) are particularly at risk. Recent estimates of coastal erosion rates in some areas are 9 to 10 metres per year (see *THREATS AND LIMITING FACTORS*).

Figure 11. Eroding Hairy Braya habitat – ice-rich permafrost is visible as white area under the active layer. Remains of Hairy Braya are sometimes found on the turfs sliding into the sea. (photo by J. Harris).

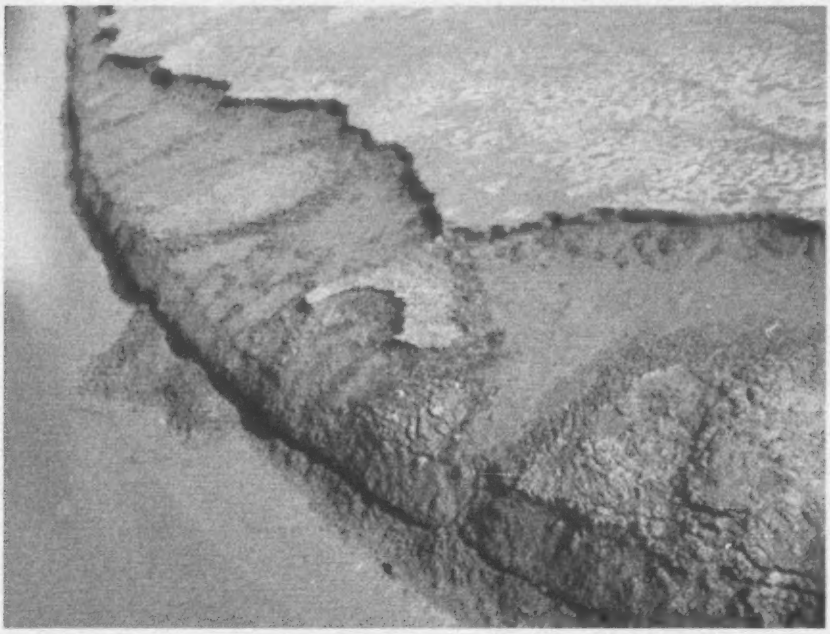

Figure 12. The erosion of the active layer appears be a result of wave undercuts, infiltration of salt water then mass failure of ice-rich permafrost (photos by S. Carrière 2011).

The recent decline of caribou in the Cape Bathurst region (Nagy and Johnson 2006) may also reduce Hairy Braya habitat due to reduced disturbance and consequent bare soil.

Inland populations of Hairy Braya, and populations along less exposed coastal areas, which together harbour more than 90% of the global population of the species, appear to be stable. More than 50% of the total population occurs in one inland site (population 6, Figure 3), in a low-lying area along an inlet that may be subjected to storm surges in the future. It is unknown what percentage of the total known range of Hairy Braya population has already been lost due to coastal erosion and salinization.

BIOLOGY

Hairy Braya was lost to science from 1850 to 2004 (Harris 2004). As a result, very little is known about the biology of the species. The morphology and distribution of Hairy Braya do allow some reasonable inferences to be made about its biology (Harris 1985, 2004), but living plants for study have been unavailable until 2011, when seeds were collected in the field (Harris 2011). Research over the next few months and years should provide a basis for a more complete understanding of the species.

Life Cycle and Reproduction

The life cycle and reproduction of Hairy Braya have not been studied. However, although most *Braya* species are self-pollinating (Harris 1985), Hairy Braya is likely cross-pollinating (Harris 1985, 2004). Although visits to Hairy Braya flowers by pollinators have not been observed in the field, the plant has several characteristics common to out-crossing species generally (Ornduff 1969), and to out-crossing *Braya* species specifically (Harris 1985, 2004). These include: large (for the genus) and fragrant flowers (Richardson 1828; Hooker 1830; Bennett and Harris, unpublished data), exceptionally long styles, rotation of corollas, a relatively high frequency of abortive silicles, a low ploidy level (Harris, unpublished data), and a narrow distribution limited to unglaciated lands. The thick taproots, many-branched root crowns, and thick thatch of old leaves and leaf bases indicate that Hairy Braya is a fairly long-lived perennial with a lifespan of approximately 15-20 years. It is believed that Hairy Braya is incapable of reproducing asexually, though no studies have been done to confirm this. A similar species, Fernald's Braya, is not known to reproduce asexually and therefore relies on sexual reproduction to maintain populations (Parsons and Hermanutz 2006).

Physiology and Adaptability

No work has been done to establish the physiology and adaptability of Hairy Braya. Nonetheless, some reasonable assumptions about the species can be made. First, the extremely limited distribution of Hairy Braya strongly suggests that the species has little ability to expand its distribution range and move onto appropriate habitat in surrounding areas. The plant's distribution pattern mirrors that of some subspecies of Low Braya (*B. humilis* subsp. *maccallae* and subsp. *porsildii*), which are also out-crossing, of low ploidy level, and limited to small areas on or near unglaciated lands (Harris 1985).

Seeds of Hairy Braya collected from Cape Bathurst in 2011 (Harris 2011) germinate readily in the greenhouse, and immature plants are easily maintained in cultivation (Harris, unpublished). Plants have not yet been raised to maturity, so studies on the reproductive biology of the plant have to date not been possible.

Dispersal and Migration

Hairy Braya possesses no obvious adaptations of the fruits or seeds for long-distance dispersal, and it has evidently been unable to expand its range as the Pleistocene ice sheets receded. Tilley (2003) found that for two other braya species, Fernald's Braya (*Braya fernaldii*) and Long's Braya (*Braya longii*), seeds rarely disperse more than 50 cm from the parent plant. Fernald's and Long's Braya also have narrow ranges on the island of Newfoundland. Tilley theorized that dispersal was the primary limitation in the colonization of new habitat patches and to the distribution of those rare species. It may be possible that some longer-distance dispersal occurs by water or on snow. While populations are separated from each other by unsuitable habitat, this fragmentation is not considered "severely fragmented" as per the IUCN definition (IUCN 2008).

Interspecific Interactions

Species of *Braya* typically do not compete well with other plant species and require bare soils (e.g. gravel bars, river banks, lake and sea shores, moraines, solifluction soils) for seedling survival (Harris 1985, 2010). It appears that most populations of Hairy Braya utilize soils that are bare due to physical processes, such as wind and water erosion and deposition of sediment, and periods of standing water denuding small patches of ground. It is likely that freeze-thaw cycles causing frost-boils, as have been documented in Newfoundland (Parsons and Hermanutz 2006), also play a role in making habitat available for Hairy Braya. However, some populations appear to be dependent on soil disturbance by caribou hooves to provide bare soils where seedlings can become established (Harris 2004).

The widespread Smooth Braya is an allopolyploid that likely arose from hybridization between two *Braya* species of lower ploidy level (Warwick *et al.* 2004). The out-crossing Hairy Braya is a likely candidate for one of the parent species (Harris 1985, 2004). There is some indication from DNA sequence data (Harris, unpublished) that some gene flow is still occurring between Hairy Braya and nearby Smooth Braya plants.

It has long been hypothesized, based on morphology (Harris 1985) and DNA sequence data (Harris, unpublished), that Hairy Braya is most closely related to Greenland Braya (*B. thorild-wulffii*), a species that is distributed primarily in Greenland and the more northerly islands in the Canadian Arctic Archipelago (Harris 2010). Greenland Braya has not been reported from continental North America, but the most southerly known populations of the species are on the southern portions of Banks Island, approximately 200 kilometres from Cape Bathurst. Fieldwork conducted on Cape Bathurst in 2011 (Harris 2011) indicates that the relationship between *B. pilosa* and *B. thorild-wulffii* needs to be re-evaluated. The large number of Hairy Braya individuals observed in the field in 2011 showed a much wider range of morphological variation than previously documented in the species. Plants ranged from large-flowered, erect individuals matching previous published descriptions of Hairy Braya (Hooker 1830; Harris 1985, 2004, 2010) to small-flowered, decumbent individuals strikingly similar to Greenland Braya. The morphological distinctiveness of these close-related species breaks down on Cape Bathurst.

It has been assumed (Harris 1985) that diploid Hairy Braya gave rise to the tetraploid Greenland Braya, and that this new polyploid species was then able to move north into high-arctic regions. However, a recent chromosome count (Harris, unpublished) from one Cape Bathurst Hairy Braya individual cast doubt on this hypothesis. This plant was tetraploid rather than diploid. It therefore appears likely that Greenland Braya arose from Hairy Braya not through polyploidy, but as a result of a shift from self-incompatibility to self-compatibility and the accompanying morphological changes (e.g. smaller flowers, shorter styles, loss of scent) associated with the selfing syndrome (Ornduff 1969; Sicard and Lenhard 2011). The newly discovered and highly variable populations on Cape Bathurst in 2011 suggest that a shift from self-incompatibility to self-compatibility in Hairy Braya is ongoing. Further work is needed to clarify the relationship between Hairy Braya and Greenland Braya.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

All estimates of population size of Hairy Braya are based on fieldwork conducted in 2011 on Cape Bathurst. Transects were run in three Hairy Braya populations, and a 1 m^2 quadrat was used to determine percent cover, plant community composition, and the number of Hairy Braya plants per m^2. Estimates of the number of individuals in these populations were based on the approximate density of the plant per square metre and the estimated dimensions of each population. The same methodology was applied to other populations of less than 300 individuals. Estimates of population size in populations of more than about 300 individuals are much less precise. Due to limited field time, the field crew needed to move quickly and cover a lot of ground. Emphasis was placed on determining the area of occurrence of the species and trying to locate as many populations as possible within that area.

Search efforts in 2011 focused on areas likely to harbour Hairy Braya populations, i.e. dry, upland areas on bluffs along coastlines, inlets, and waterways (Figure 13). Likely areas covered on foot in the most northerly portion of Cape Bathurst were searched thoroughly, while more southerly portions of the peninsula covered by helicopter were of necessity spot-checked. The most likely area with as yet undiscovered additional populations of Hairy Braya is indicated on Figure 13 (blue-grey areas in region E of the map).

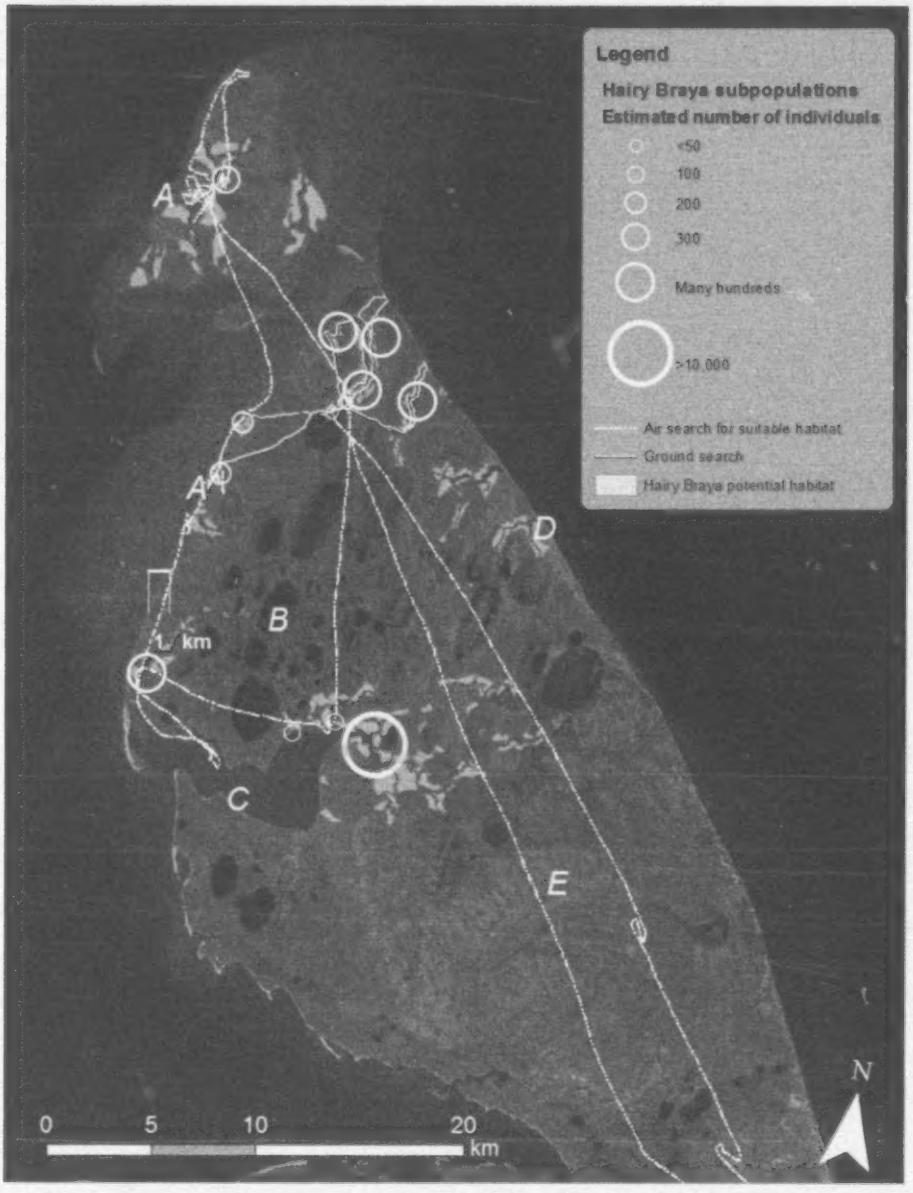

Figure 13. Potential habitat for *Braya pilosa* on Cape Bathurst peninsula and Baillie Islands. Components for potential habitat were determined during both walking (blue solid line) and helicopter (white dashed line) surveys. Components included dry land (showing blue-grey on satellite image) and close vicinity of a stream, providing some drainage in spring. Notes on map: (A) Shorelines with severe loss of habitat with measured slumping rates into the sea at about 9.5 m/yr. Additional mortality in this zone was noted due to salt sprays. Marker for 1 km corresponds to projected habitat loss over the next 100 years if rates remain constant. (B) Terrain confirmed as too wet to contain *B. pilosa*. (C) Terrain confirmed as too sandy to contain *B. pilosa*. (D) Shorelines with severe loss of habitat of unknown rate and, further south, with soot deposits due to oil shale fires along banks (Smoking Hills). (E) Inland site confirmed without *B. pilosa*. Additional dry terrain immediately west of (E) has not been visited. Satellite imagery source: ESRI, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community. For more information on this map, go to http://goto.arcgisonline.com/maps/World_Imagery.

Abundance

Due to field time constraints, precise counts of the number of Hairy Braya individuals could not be made. Populations estimated to be of 300-1000 individuals are listed as "many hundreds," and one very large population could only be estimated as greater than 10,000 individuals (Figure 3). The best estimate of the total number of individuals observed in 2011 is somewhere between 15,000 and 20,000. Approximately 80% of the total number of individuals, or 12,000 to 16,000, were reproductively mature. However, only half of the habitat considered to have the highest potential for the plant occurrence has been surveyed (Figure 13).

Fluctuations and Trends

Trends in abundance cannot be inferred for most populations because only one population has abundance information for more than one year. Populations on coastal bluffs have in the recent past been, and continue to be, subject to rapid erosion and saline mortality. The total number of individuals in the northwest coastal population (Figure 3) that was visited in both 2004 and 2011 has declined from several hundred to approximately 100 individuals over that seven-year period. It can be expected that similar populations on eroding shorelines will be similarly affected.

Based on current coastal erosion rates of approximately 9.5 m per year (Schwarz 2011), roughly 2% of the known total number of mature Hairy Braya individuals will be eliminated over the next five years, and roughly 5% over the next ten years. Essentially, all four coastal at-risk populations of Hairy Braya (about 15% of all the known populations, see starred populations on Figure 3) can be expected to be gone within 100 years. The largest population on the western side of the peninsula occurs in low-lying areas on the inlet that may be affected by future storm surges. Trends and fluctuations in populations on the more protected sections of the coast and on inland bluffs have not been determined, but these populations appear to be stable.

The absence of population information between 1850 and 2004 is not due to a population trend or fluctuation, but rather a mistaken locale description from 1850 that led astray anyone searching for the species thereafter. The ecology of the species and other similarities to other *Braya* species makes it unlikely to experience significant population fluctuations in the short term.

Rescue Effect

Hairy Braya is endemic to Cape Bathurst and Baillie Islands. It is apparently unable to colonize adjacent similar habitat, and there are no known surrounding populations.

THREATS AND LIMITING FACTORS

The most obvious threat to Hairy Braya is a loss of habitat due to rapid erosion and salinization of northwest and western coastline habitat. Increasing rates of coastal erosion and storm surges due to a significant reduction in ice cover on the Beaufort Sea over the past few decades and the subsequent mass wasting of exposed permafrost is well documented (e.g. Rachold *et al.* 2005; Lantuit *et al.* 2008; Jones *et al.* 2009; Lantuit *et al.* 2011). Recent estimates of coastal erosion rates near several Hairy Braya populations along the northwestern coast of Cape Bathurst, based on high-resolution satellite imagery, are 9 to 10 metres per year over the past 38 years (Schwarz 2011). Due to warming of the earth's atmosphere, which is expected to continue into the foreseeable future, it is very likely that storm surges, coastal erosion and salinization will increase along the Beaufort Sea coast (Kokelj *et al.* 2012). For Hairy Braya, the most serious threat is loss of habitat along northwest-facing shorelines. All populations within one km of rapidly eroding shorelines and coasts susceptible to future storm surges may face extirpation within 100 years. Five populations (Figure 3, populations 3, 4, 5, 11 and 12), consisting of approximately 15% of the total known number of Hairy Braya individuals, are found along the rapidly eroding northwestern shorelines (see starred populations on Figure 3). In addition, storm surges are possible in the future where the largest set of populations (Figure 3 populations 1, 2, 6, 7, and 8) exist along low-lying areas and inlets on the western shores of the peninsula.

The most plausible threats for other populations are less clear but may include local stochastic events due to changes in water availability (e.g., drought, flooding) or to natural disturbances.

Defining Locations

It is recommended by the IUCN (2008) that where a species is affected by more than one threatening event, 'location should be defined by considering the most serious plausible threat'. Therefore the coast populations (Figure 3, populations 3, 4, 5, 11, 12) can be categorized as a single location. Storm surges are the greatest threat to populations 1, 2, 6, 7, and 8 (Figure 3) that exist along low-lying areas and inlets on the western shores of the peninsula and Bailie Island and thus represent a second location. The remaining populations (Figure 3, populations 9, 10, and 13) are considered separate locations for a total of 5. This may be considered a minimum as a few potential habitats somewhat protected from the main threat have not been surveyed (Figure 13).

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

At the time of assessment in April 2013, Hairy Braya did not benefit from any legal protection. It has not been assessed by the IUCN. The species has been assessed as Threatened in the Northwest Territories (SARC 2012), and this assessment is in consultation for possible legal listing under the *Species at Risk (NWT) Act*.

Non-Legal Status and Ranks

Hairy Braya is currently ranked as critically imperilled both globally (G1) and nationally (N1) but is not ranked in the Northwest Territories (SNR) (NatureServe 2012). The species is designated with a General Status rank of GS2 (May Be at Risk) by Northwest Territories (Canadian Endangered Species Conservation Council 2011).

Habitat Protection and Ownership

Hairy Braya is restricted to the Inuvialuit Settlement Region in the Northwest Territories. Although Cape Bathurst does not have a protective legal designation, Inuvialuit management of the Inuvialuit-owned lands provides some control over direct human activities that might threaten Hairy Braya.

Due to the remote locality of Cape Bathurst, Hairy Braya faces little direct threat from human activities. The Cape Bathurst is Inuvialuit private land (Indian Affairs and Northern Development 1984) and includes the sensitive calving grounds of the Cape Bathurst caribou herd. Conservation priorities for the area have been formalized in the Tuktoyaktuk Community Conservation Plan, which states that the area includes resources of particular significance and sensitivity throughout the year, and recommends that the area be managed so as to eliminate, to the greatest extent possible, potential anthropogenic damage and disruption (TCCP 2008). Proposals for development projects are screened by the Inuvialuit Land Administration (ILA). The ILA normally requires the approval of the Inuvialuit Hunters and Trappers Committees before approving project proposals, and can also attach conditions on the projects to ensure that land and resources are not harmed (TCCP 2008).

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

James G. Harris received his Ph.D. in 1985 from the University of Alberta. His Ph.D. project was a taxonomic and phylogenetic study of the plant genus *Braya* (Brassicaceae) in North America. His current research interests include the taxonomy, phylogenetics, and phylogeography of North American *Braya* and *Draba* (Brassicaceae) species, and the floristics of alpine regions in the Great Basin of the western United States. He is a Professor of Biology and the Director of the Herbarium at Utah Valley University, where he has been employed since 1986.

COLLECTIONS EXAMINED

Hairy Braya has been collected four times prior to 2011: John Richardson *s.n.*, 1826, 1848; William Pullen *s.n.*, 1850; James Harris and Daniel Taylor coll.# 3644, 2004. The Richardson and Pullen collections are located in the Royal Botanic Gardens Herbarium (K) at Kew, England, and the Harris and Taylor collection (and duplicates) is located at the following herbaria: Utah Valley University (UVSC), Agriculture and Agri-Food Canada (DAO), Canadian Museum of Nature (CAN), Missouri Botanical Garden (MO), New York Botanical Garden (NY), and University of Alaska (ALA). The report writer has examined all of these collections. Specimens collected during fieldwork conducted in 2011 were also examined, but these have not yet been distributed to permanent collections (UVSC, DAO, CAN, MO, NY, and ALA).

Appendix A: Extent of the ice at the last glacial maximum, from Dyke *et al.* (2003). Shortly after glaciers retreated Cape Bathurst and Baillie Islands were part of a large glacio-fluvial delta.